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1-D SEMICONDUCTING NANOWIRES AND THEIR ASSEMBLY

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ABSTRACT

Nanowires, the one-dimensional(1D) semiconducting structures are one of the most potent and flexible classes of synthetically reconfigurable nanoscale basic elements widely used for examining the basic physical characteristics of nanomaterials and assembling a range of functional nanostructure systems. To design these functional nanostructure systems, it is critical to guarantee that the synthesis of these structures, as well as their assembly, are exceedingly exact and precise. The synthesis and assembly of these nanostructures is what defines the success of the nanostructure systems. Nanowire assembly is challenging because the required length scales prohibit direct interaction and increase the instability aspects of electrostatic forces and mass transfer. This paper focuses on the different core assembly methodologies of one-dimensional semiconductor nanowires into desired designs for functional nanostructure systems.

KEYWORDS: Synthesis, Self assembly, Reconfigurable nanoscale, Nanostructure, Electrostatic forces

1. INTRODUCTION

Nanotechnology has emerged as one of the most exciting areas of research. Soon, it is projected to have a massive societal and economic influence. Existing nanotechnology, such as nanowires and the increasing amount of transistors on a system, hint in this direction. Nanomaterials research on the nanoscale scale is a significant component of nanotechnology. Attempting to understand how materials' properties emerge, and much more importantly, to exploit or attain best properties, is crucial.[1][2]

Nanowires are one-dimensional structures which can be used to construct broader nanostructures. Nanowires exhibit distinct electrical, heat and other engineering properties, particularly along the entire length. Using these characteristics would offer up a plethora of electronic applications. In addition, these structures have been of interest, because of the extensive range of synthesis processes available. Most of them are inexpensive in aspects of synthesis and assembly.[1][2]

Significant work has been done into creating ways of assembling one dimensional nanostructure: nanowires to build functional nanostructures and realize their potential applications. As an example, assembling Nanowires on selected substrates for future applications often involves two approaches: the first is aligned nanowire development, and the second is transport of the oriented nanowires to the desired substrates.[1][2]

There have been several advancements in the production of one-dimensional nanowires. To synthesize and assemble these nanostructures, both top-down and bottom-up techniques are used. It is as shown in Figure1. The latter has an essential advantage in terms of higher accuracy and application-specific techniques. Bottom-up techniques are used in the self-assembly of nanowires. There are few key bottom-up assembly approaches that will be covered in the following sections.[1][2]

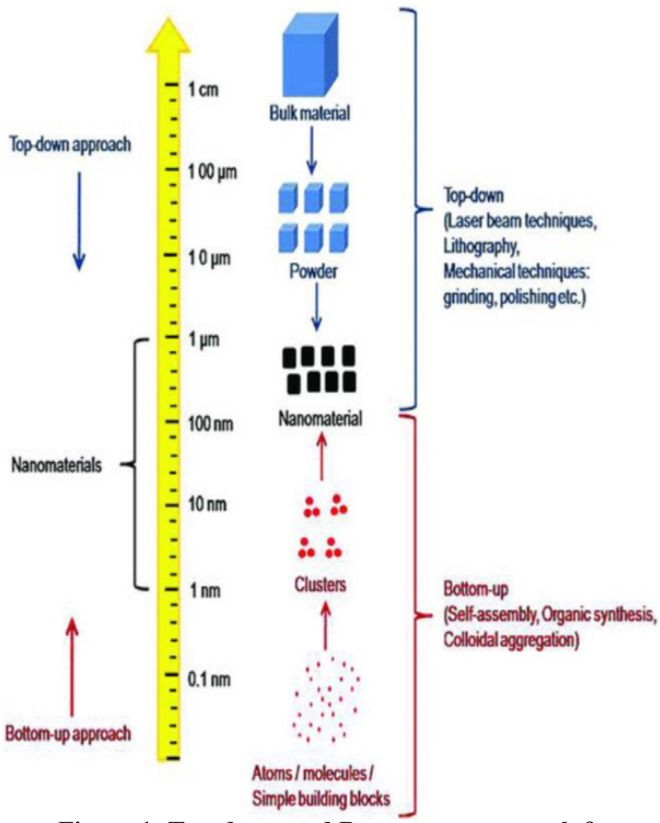

Figure 1: Top-down and Bottom-up approach for Nanotechnology

Nanowires can be synthesized using the following methods:

1. VLS (Vapor Liquid Solid) Method
2. FLS (Fluid Liquid Solid) Method
3. SLS (Solution Liquid Solid) Method
4. OAG (Oxide Assisted Growth) Method

Since our focus of this paper is on assembly techniques of nanowires, the synthesis of these structures will not be covered.

2. ASSEMBLY OF NANOWIRES

It is vital that effective application and development of efficient and precise procedures for con-trolled organization and assembly of nanowires take place. This phase is critical because it serves as the foundation for the nanostructure blocks necessary for applications. To integrate these 1D nanowires into arrays with precise alignment and position, efficient processes are required.

A great deal of progress has been achieved in developing effective procedures for building these structures by using elements such as electric field application, micro-fluidic flow, optical traps produced in the fluid to manipulate the nanowires, and so on. We will go through a few essential technologies for assembling one-dimensional nanowires into nanostructures such as Langmuir-Blodgett Method, Electri-cal field-assisted Method, Optical Trap Method, Micro fluid-based method, Chemical Driven based method and Contact Printing Method.

3. LANGMUIR-BLODGETT METHOD

The Langmuir-Blodgett method is designed to transfer thin films of organic materials onto a sub-strate to form incredibly thin films with a great degree of structure order, and it has been discovered to be a potent method to achieve NW assembly on higher densities scales with precise NW widths down to the nanometer level and controlled densities.[2][3][4][7]

A surfactant-wrapped nanowire monolayer was originally produced on the surface of the liquid in an LB trough during the nanowire assembly process. Surfactants bind around the surface of the nan-owires, permitting the wires to be spread in a fluidic media and afloat at the fluid-air junction. The layer was again compressed with a LB trough barrier with the suitable compression level. To decrease the sur-face energy of the liquid, the nanowires were tightly packed in parallel arrays with its vertical orienta-tions positioned perpendicular to direction of compression, and the monolayer was then deposited onto a substrate using vertical-dipping or horizontal-lifting procedures. By attempting to control the lifting speed and compression pressure, the gap between the parallel nanowires could be precisely regulated. This technology was successfully used to create well-aligned nanowires with regulated spacing from the nanometer to the micrometer scale, which were then transferred to planar substrates through a layer-by-layer (LBL) procedure to build parallel and crossing nanowire architectures. The constructed nanowire structures were then photolithographically shaped into repeating arrays of specified dimensions and pitch, yielding hierarchical structures over numerous length scales from nanometer through centimeter ordering. This research shows that this technology is a potential way for large-scale assembly of every nanowire element into tightly integrated and hierarchically ordered nanodevices capable of supporting a wide range of functional nano systems.[2][3][4][7]

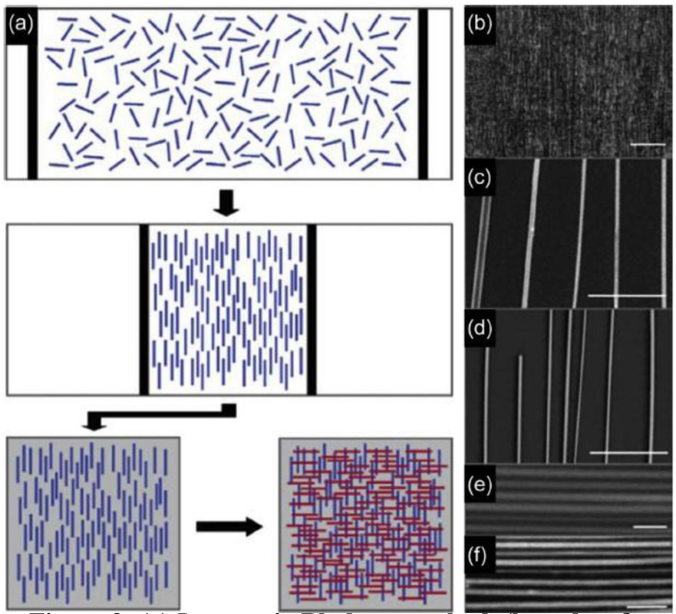

Figure 2: (a) Langmuir-Blodgett method, (b, c, d, e, f)– Nanowires deposited and aligned parallel on substrate.

4. ELECTRICAL FIELD-ASSISTED METHOD

Typically, nanowires are immersed in a solvent above contact pads to which a charge is delivered. The nanowires then shift, encountering a force that leads them to position themselves on the substrates in relation towards the contact pads. It is feasible to guide both reversible and irreversible assembly of nan-owires in a variety of designs by altering the solvent, size of the nanowires, geometry and space between the electrodes, frequency, and field intensity. This is as depicted in Figure 3 A considerable number of nanowires might be aligned along the field direction using parallel electrodes. This arrangement of nan-owires between electrodes demonstrates how individual wires may be placed to bridge pairs of opposing electrodes and produce a parallel ordered array. In addition, the alignment might be carried out in a Lay-er - by - layer form to provide crossed nanowire intersections. The electric field-assisted assembly ap-proach may provide decent directional as well as spatial control of nanowire alignment.[2][3]

Another method that can be used is the DEP method or Dielectrophoresis. It is the migration of neu-tral particles in the presence of a non-uniform electric field. This occurs when neutral particles become polarized and encounter various forces at the extremities of a polarized dipole due to a non-uniform elec-tric field at these ends. The difference forces the polarized particles towards locations of varying field intensity. These fields can guide the nanowires into assembling as discussed in the above para-graphs.[2][3]

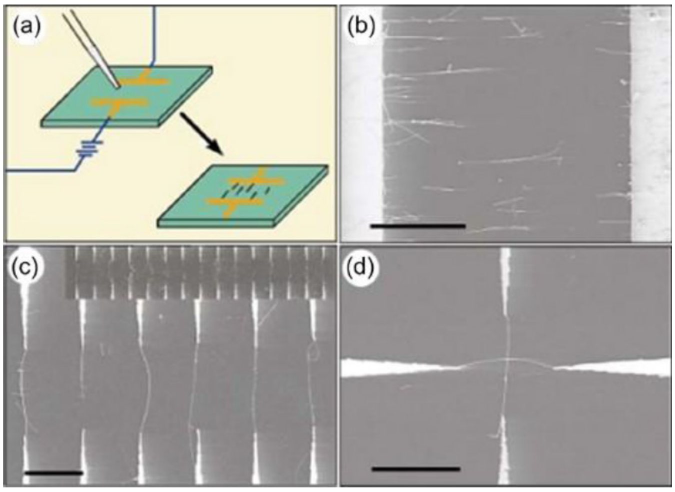

Figure 3: Electric field-assisted Method (a)-Biasing of electrodes on the substrate (b)-Parallel Nanowire array (c)-Nanowire spatial position (d)-Nanowire interconnected junction

5. OPTICAL TRAP METHOD

This method of optical trapping offers the benefit of being able to combine semiconductor NWs into complex heterostructures in three dimensions with good angular and spatial accuracy in 3D orientations. It also demonstrates the capacity to act in situ in closed aqueous chambers, the potential application to a broad variety of materials, and the adjustability of their intensity, wavelength, and polarization using lasers, modulators, and holographic optical components. The nanowires were captured by directing the laser traps at one end of the nanowire and then shifting the trap through the wire while elevating the trap at the same time. Once the nanowires were firmly trapped, one end of the wire was in laser focus and remainder wire was parallel to optical axis, resulting in a 3D confinement. The trapped nanowires may be translated further using a home-built translation phase for vast distances or three-axis piezo-stage for precise control. In three axes, speeds of up to 10 mm/s were possible. A concentrated infrared ray inside the optical capture system may also be used to fuse two wires. b y using a greater intensity laser irradiation than that used for. This is as shown in Figure 4.[2][4][5]

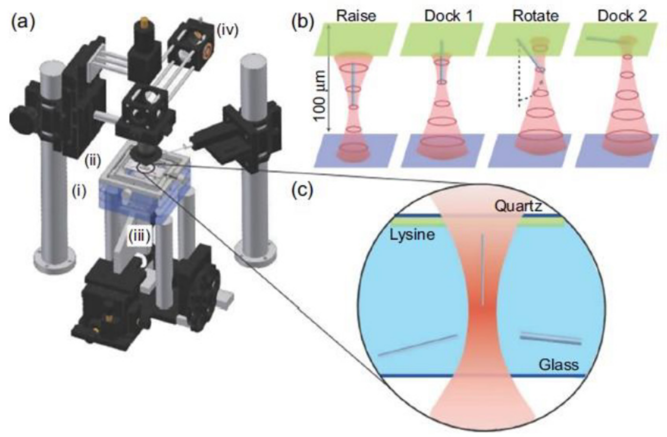

Figure 4: (a)-Optical Trapping method, (b, c)-Cross section view of chamber

6. MICRO-FLUID BASED METHOD

Layered assembly of nanowires is also possible in working fluid with regulated separation and spatial placement. Aside from parallel arrays of nanowires, the approach might also be used layer-by-layer to create crossing nanowire arrays with various flow directions for consecutive stages. The flow rate can influence the degree of alignment. With rising flow rates, the thickness of the nanowires with respect to flow narrows. This is due to increased shear forces created by greater flow rates. Furthermore, the flow duration can influence the average nanowire surface coverage. The density of nanowires increases as the time increases. The chemical properties of substratum surfaces are also crucial in nanowire assembly. The shortest distance between aligned NWs that may be obtained without wire connections is determined by the lengths of nanowires utilized in assembly.

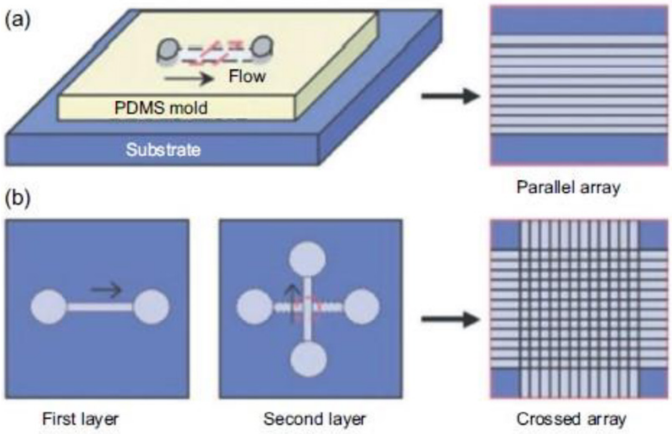

Figure 5: Micro-fluidic assembly Technique (a) Aligned nanowires within a magnetic field (b) Nanowire self-align along magnetic field lines (c) Nanowires assembled using arrays of patterned magnets

7. CHEMICAL DRIVEN BASED METHOD

To circumvent the lack of control over specificity and tunability between nanowires and substrates, organic compounds are utilized on a substrate to influence the building of carbon nanotubes (Single - walled carbon) on a large scale. The essential concept underlying this technology is to organize diverse types of functional semiconductor nanowires by forming complimentary chemical contacts between its surfaces and substrates. Two separate surface patches on substrate were formed; one was wrapped with polar groups (amino or carboxyl), while the other was covered with non-polar groups (methyl). Following that, the substrate was submerged in a slurry of single-walled nanotubes, which were also chemically bound to the polar areas and assembled to create specified shapes. If the surfaces of the semiconductor nanowires were correctly changed, chemically guided assembly might be employed on them as well. Inert surface molecule patterns are employed to control the adsorption and aligning of nanowires onto exposed surface areas on the substrates. In addition to chemical molecules, biomolecules such as DNA may be utilized to make complicated structures from molecular building blocks, satisfying the demands for precise nanofabrication. It is shown in Figure 6.[2][3][4]

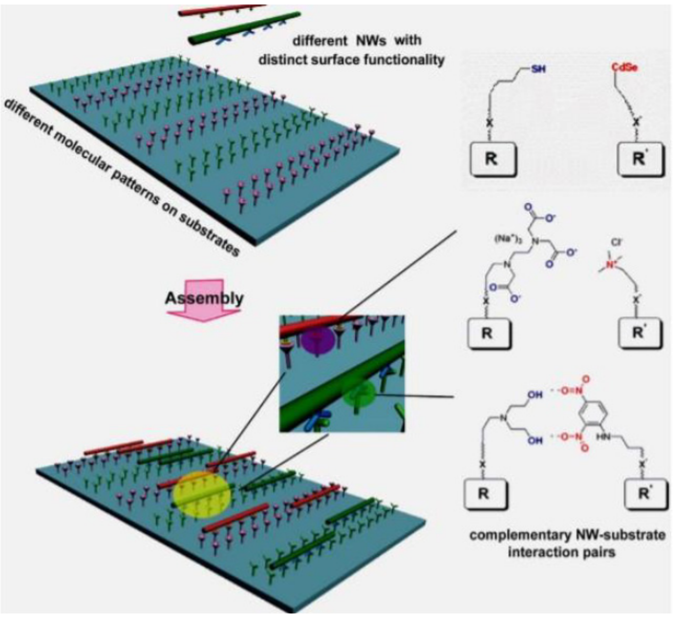

Figure 6: Chemically driven assembly of Nanowires

8. CONTACT PRINTING METHOD

The entire process of contact printing approach consists of two primary steps: (1) enhancing the ori-entated development of planned Nanowires by nanocluster device, and (2) structured transferring of the Nanowires directly from a nanowire growth substrate to a secondary semiconductor substrate through contact printing. Accordingly, photolithography-patterned substrate is tightly connected to a tabletop, and the nanowire growth substrate is then positioned inverted on top of patterned substrate, with the Nanowires in contact with the device substrate. A slight hand pressure is then given from the top, followed by moving the growing substrate. Finally, the growing substrate is removed. Shear force is formed during assembly process by the movement of fluid or solid entity against a second object.[2][3][4]

To gain stacked electronic layers, the nanowire printing steps are repeated multiple times, together with deposition of an insulating SiO2 buffer layer. This procedure is applicable to a wide variety of documented nanowire materials and device designs; additionally, the method's simplicity and low processing temperature requirement make it excellent for generating high-performance 3D-integrated circuits with varied functionality in discrete layers.[2][3][4]

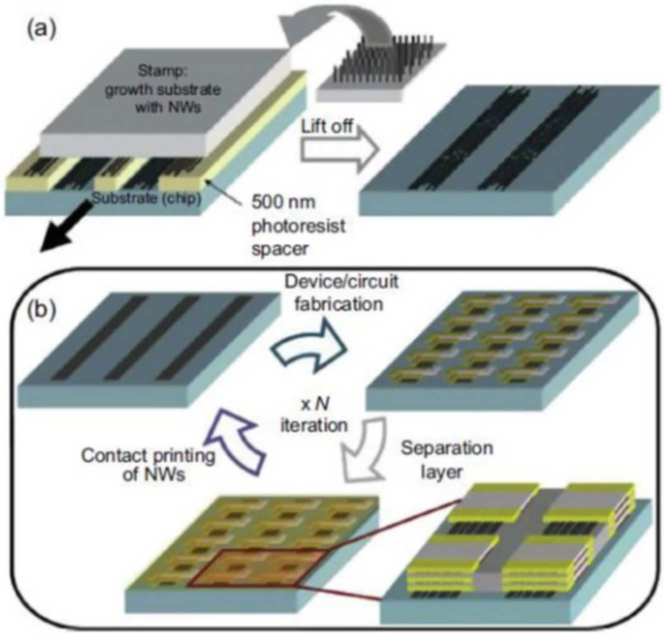

Figure 7: (a, b)- Contact Printing Method

9. CONCLUSION

Nanowires are the essential building elements used to construct nanodevices such as diodes and transistors. Various methods have been applied in the fabrication and assembly of these entities. This paper has described a few new technological advances in the assembly of these Nanowires into desirable topologies. The approaches outlined above are quite successful for obtaining regulated development and guided alignment. These bottom-up techniques face major challenges in spatial placement, throughput, and tolerability. Further research is needed at this point to increase the yield and accuracy of these approaches. Nanoscale-based architectures and systems will continue to innovate and enhance user experience over time.

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